



General

Guideline Title

ACR Appropriateness Criteria® thoracic aorta interventional planning and follow-up.

Bibliographic Source(s)

Bonci G, Steigner ML, Hanley M, Braun AR, Desjardins B, Gaba RC, Gage KL, Matsumura JS, Roselli EE, Sella DM, Strax R, Verma N, Weiss CR, Dill KE, Expert Panels on Vascular Imaging and Interventional Radiology. ACR Appropriateness Criteria® thoracic aorta interventional planning and follow-up. Reston (VA): American College of Radiology (ACR); 2017. 17 p. [92 references]

Guideline Status

This is the current release of the guideline.


This guideline meets NGC's 2013 (revised) inclusion criteria.

NEATS Assessment

National Guideline Clearinghouse (NGC) has assessed this guideline's adherence to standards of trustworthiness, derived from the Institute of Medicine's report [Clinical Practice Guidelines We Can Trust](#).

■■■■= Poor ■■■= Fair ■■■= Good ■■■= Very Good ■■■= Excellent

Assessment	Standard of Trustworthiness
YES	Disclosure of Guideline Funding Source
■■■■	Disclosure and Management of Financial Conflict of Interests
	Guideline Development Group Composition
YES	Multidisciplinary Group
YES	Methodologist Involvement

	Patient and Public Perspectives
	Use of a Systematic Review of Evidence
	Search Strategy
	Study Selection
	Synthesis of Evidence
	Evidence Foundations for and Rating Strength of Recommendations
	Grading the Quality or Strength of Evidence
	Benefits and Harms of Recommendations
	Evidence Summary Supporting Recommendations
	Rating the Strength of Recommendations
	Specific and Unambiguous Articulation of Recommendations
	External Review
	Updating



Recommendations

Major Recommendations

[ACR Appropriateness Criteria®](#)

[Clinical Condition](#): Thoracic Aorta Interventional Planning and Follow-Up

[Variant 1](#): Planning for pre-thoracic endovascular repair (TEVAR) of thoracic aorta disease.

Radiologic Procedure	Rating	Comments	RRL*
CTA chest abdomen pelvis with IV contrast	9	See references 10,11,24-26,38-54,56-58 in the original guideline document.	
CTA chest with IV contrast	7	This procedure is appropriate if pathology is contained to the thoracic aorta. See references 10,11,24-26,38-54,56-58 in the original guideline document.	
MRA chest abdomen pelvis with IV contrast	7	See references 10,36,39,60,61 in the original guideline document.	O
MRA chest with IV contrast	7	This procedure is appropriate if pathology is contained to the thoracic aorta. See references 10,36,39,60,61 in the original guideline document.	O
MRA chest abdomen pelvis without IV contrast	6	See references 10,11,24-26,38-54,56-58 in the original guideline document.	*Relative Radiation

Radiologic Procedure	Rating	Comments	RRL*
		36,39,60 in the original guideline document.	
MRA chest without IV contrast	6	This procedure is appropriate if pathology is contained to the thoracic aorta and if contrast is contraindicated. See references 36,39,60 in the original guideline document.	O
US duplex Doppler iliofemoral arteries	5	This procedure may be appropriate as an adjunctive for preoperative access site planning. See references 56,68 in the original guideline document.	O
Aortography chest abdomen pelvis	5	This procedure may be appropriate for diagnostic purposes when urgent intervention is required. See references 45,56,61,93,64 in the original guideline document.	☢☢☢☢
US echocardiography transeophageal	5	This procedure is useful as an adjunctive study or for urgent/intraoperative evaluation but does not provide complete evaluation of the thoracic aorta and its branch vessels. See references 54,59,61,65,66 in the original guideline document.	O
CT chest abdomen pelvis without IV contrast	4	This procedure may have utility in cases of suspected intramural hematoma, in situations where patients cannot receive iodinated contrast, and/or where MRI is contraindicated. See references 10,11,24-26,38-54,56-58 in the original guideline document.	☢☢☢☢
CT chest without IV contrast	4	This procedure may have utility in cases of suspected intramural hematoma, in situations where patients cannot receive iodinated contrast, and/or where MRI is contraindicated. See references 10,11,24-26,38-54,56-58 in the original guideline document.	☢☢☢
US echocardiography transthoracic resting	4	See references 54,59,61,65,66 in the original guideline document.	O
US intravascular aorta	4	This procedure may be useful as an adjunctive intraprocedural technique. See reference 67 in the original guideline document.	O
CT chest abdomen pelvis without and with IV contrast	3	See references 2-14,33,34,61,71-83 in the original guideline document.	☢☢☢☢
CT chest abdomen pelvis with IV contrast	3	CTA is the preferred examination. See references 2-14,33,34,61,71-83 in the original guideline document.	☢☢☢☢
CT chest without and with IV contrast	3	Use this procedure if contrast can be given. CTA is the preferred examination (CTA can include a noncontrast phase as per the ACR definition).	☢☢☢
CT chest with IV contrast	3	Use this procedure if contrast can be given. CTA is the preferred examination.	☢☢☢
FDG-PET/CT chest abdomen pelvis	3	See reference 70 in the original guideline document.	☢☢☢☢
X-ray chest	2	See references 59,69 in the original guideline document.	☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation

Radiologic Procedure	Rating	Comments	level RRL*
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Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 2: Follow-up for post-thoracic endovascular repair (TEVAR) of thoracic aortic disease.

Radiologic Procedure	Rating	Comments	RRL*
CTA chest abdomen pelvis with IV contrast	8	See references 12-14,33,34,61,71-83 in the original guideline document.	⊕⊕⊕⊕⊕
CTA chest with IV contrast	8	This procedure is appropriate if pathology is contained to the thoracic aorta. See references 12-14,33,34,61,71-83 in the original guideline document.	⊕⊕⊕
MRA chest abdomen pelvis with IV contrast	6	MR should primarily be considered if stent material allows for diagnostic MRI (e.g., nitinol). See references 39,61,74,84,87-89 in the original guideline document.	O
MRA chest with IV contrast	6	This procedure should primarily be considered if stent material allows for diagnostic MRI (e.g., nitinol) and if pathology is contained to the thoracic aorta. See references 39,61,74,84,87-89 in the original guideline document.	O
MRA chest abdomen pelvis without IV contrast	5	This procedure may be useful if stent is compatible and if contrast is contraindicated. See references 39,61,74,84,87-89 in the original guideline document.	O
MRA chest without IV contrast	5	This procedure may be useful if stent is compatible, if contrast is contraindicated, and if pathology is contained to the thoracic aorta. See references 39,61,74,84,87-89 in the original guideline document.	O
Aortography chest abdomen pelvis	5	This procedure is not for routine follow-up but may be useful if the source of endoleak is unclear on cross-sectional imaging. See reference 76 in the original guideline document.	⊕⊕⊕⊕
CT chest abdomen pelvis without IV contrast	4	This procedure may be useful for follow-up in stable patients, with addition of CTA if there is a change over time. See references 12-14,33,34,61,71-83,86 in the original guideline document.	⊕⊕⊕⊕
CT chest without IV contrast	4	This procedure may be useful for follow-up in stable patients in whom pathology is contained to the thoracic aorta, with addition of CTA if there is a change over time. See references 12-14,33,34,61,71-83,86 in the original guideline document.	⊕⊕⊕
US echocardiography transesophageal	4	See references 61,84 in the original guideline document.	O
US echocardiography transthoracic resting	4	See references 61,84 in the original guideline document.	O
X-ray chest	4	This procedure may be helpful for assessment of stent migration and graft fracture. See references 38,71 in the original guideline document.	⊕
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually			*Relative

Radiologic Procedure	Rating	Comments	RRL*
CT chest abdomen pelvis without and with IV contrast	2	Use this procedure if contrast can be given. CTA is the preferred examination (CTA can include a noncontrast phase as per the ACR definition). See references 12-14,33,34,61,71-83 in the original guideline document.	☢☢☢☢
CT chest abdomen pelvis with IV contrast	3	CTA is the preferred examination. See references 12-14,33,34,61,71-83 in the original guideline document.	☢☢☢☢
CT chest without and with IV contrast	3	Use this procedure if contrast can be given. CTA is the preferred examination (CTA can include a noncontrast phase as per the ACR definition). See references 12-14,33,34,61,71-83 in the original guideline document.	☢☢☢
CT chest with IV contrast	3	Use this procedure if contrast can be given. CTA is the preferred examination.	☢☢☢
US duplex Doppler aorta abdomen	2	This procedure will provide useful information only for the abdominal portion of the stent graft (if this applies to the patient) and cannot be reliably used in the chest, given the poor acoustic window. See references 38,90 in the original guideline document.	0
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Summary of Literature Review

Introduction/Background

Since the first thoracic aorta endograft device was approved by the Food and Drug Administration (FDA) in 2005, thoracic endovascular aortic repair (TEVAR) has undergone rapid evolution and is now applied to a range of aortic pathologies, including trauma, aneurysm, dissections, intramural hematoma (IMH), penetrating atherosclerotic ulcer (PAU), and even persistent congenital malformations such as aortic coarctation. TEVAR has also been used as a bridge treatment prior to open repair in patients with aortic infections who develop circulatory collapse or fistulization to adjacent structures. Compared to open surgical repair, TEVAR has demonstrated favorable perioperative morbidity and mortality data for many forms of thoracic aorta pathology. TEVAR also allows for intervention in patients with more extensive comorbidities that would otherwise preclude open surgical repair. In certain patient groups, including variant anatomy such as aberrant right subclavian artery with aneurysmal degeneration of the vessel origin, hybrid open and endovascular procedures are performed wherein affected visceral branch vessels are surgically revascularized with concomitant or staged endovascular exclusion of the primary aortic pathology.

Thoracic aortic aneurysms are defined as permanent dilation of the thoracic aorta by more than 2 standard deviations over the mean. Based on population studies, the thoracic aorta is generally considered aneurysmal at 4 cm. Up to one-third of thoracic aortic aneurysms extend into the abdominal aorta, increasing complexity of endovascular or surgical repair. Intervention is indicated when aneurysm diameter exceeds 5.5 cm or demonstrates rapid growth. More conservative thresholds are implemented in patients with underlying connective tissue disorders or a bicuspid aortic valve.

Acute aortic syndromes, broadly defined as a disease spectrum encompassing PAU, IMH, and aortic dissection, may be treated with conservative medical therapy or surgical/endovascular intervention, depending on the presentation. The goal of endovascular stent grafting in these conditions is to maintain true lumen patency, prevent aneurysmal degeneration, and, in the case of dissection, seal intimal tears

and induce thrombosis in the false lumen. When clinically suspected, acute aortic syndrome requires immediate diagnostic evaluation to exclude an impending vascular catastrophe. Indications for surgical intervention in these conditions include lack of symptomatic improvement with medical therapy, resistant hypertension, rapid expansion of IMH or false lumen, and concern for impending rupture. It has been shown that nearly 50% of acute aortic syndrome patients will develop a recurrent acute aortic event within 1 to 2 years of initial presentation, underscoring the need for close follow-up in this population.

With the exception of trauma, the vast majority of aortic pathologies arise in patients aged 60 to 80 years. Risk factors include male gender, long-standing hypertension, hyperlipidemia, arteriosclerosis, and smoking. However, there are a variety of genetic syndromes and single gene mutation conditions that confer a higher risk of thoracic aortic aneurysm and dissection in younger patients, including Marfan syndrome (associated with *FBN1* mutations), Loeys-Dietz syndrome (associated with *TGFB* and *SMAD* mutations), and familial thoracic aorta aneurysm leading to aortic dissections (associated with *ACTA2* mutations). Even when syndromes are not suspected, patients with a bicuspid aortic valve or a strong family history of aortic disease have higher risk of developing aneurysmal disease of the thoracic aorta. Inflammatory vasculitides such as Behçet disease and Takayasu arteritis may result in arterial stenoses, aortic pseudoaneurysm, and anastomotic dehiscence in cases of prior surgical repair, all of which have been effectively treated with TEVAR. Clinicians encountering patients with known or suspected genetic risk factors or inflammatory vasculitides should have a high suspicion for acute aortic pathology in the appropriate clinical scenario, as well as a low threshold for imaging.

Regardless of the pathology at play, the TEVAR procedure is similar. Access in TEVAR procedures is increasingly obtained percutaneously via the common femoral artery, although femoral artery cutdowns are still performed in up to 20% of cases. Although obesity was once considered a relative contraindication to percutaneous access, recent literature has demonstrated that it does not affect procedural success rates in the hands of an experienced surgeon/interventionalist. The most important factor in percutaneous vessel selection appears to be vessel diameter, with common femoral artery diameters >8 to 9 mm exhibiting lower rates of complication.

Careful attention to preoperative imaging is then paid to the involved landing zones of the thoracic aorta. Proximal and distal landing zones should ideally be 2 to 3 cm in length to ensure an adequate seal and decreased rates of endoleaks, aneurysmal degeneration, and device migration. When the proximal landing zone approaches the aortic arch vessels, the possibility of the stent graft occluding a vessel ostium arises. In such cases, vascular bypass or a staged/hybrid approach may be necessary to ensure patency. If aortic pathology extends into the abdominal aorta, care must be taken to assess for possible stent coverage of major branch vessels; when this situation arises, more involved repairs are necessary.

Despite the promise of TEVAR, it must be emphasized that the procedure is technically complex and has significant perioperative mortality of up to 12.5%, as reported in one series examining thoracoabdominal aneurysm endograft repair. Frequent intraoperative complications include damage of the target vessel and its branches, device malposition, and access problems. Significant perioperative complications abound, including stroke, persistent renal dysfunction, and paraplegia or paraparesis secondary to spinal cord ischemia. As late endoleaks have been reported in 10% to 41% of cases, continuous surveillance imaging is necessary to gauge the need for reintervention. Additional postoperative complications include progressive aneurysmal degeneration of the aorta as well as potentially life-threatening complications such as retrograde dissection.

A commonly cited disadvantage of TEVAR with respect to open repair is the high rate of reintervention. For example, a recent study demonstrated a 32% reintervention rate at 4.7 years following aortic dissection repair. A caveat is that the presence of an existing endograft can reduce operative risk in subsequent procedures. In cases of distal aneurysmal degeneration in the setting of prior TEVAR for chronic type B dissection, the indwelling endograft can serve as the attachment point for a new aortic graft, thereby reducing the extent and risk associated with reintervention.

Open surgical repair remains the treatment of choice in cases of acute Stanford type A dissection. This is because of the myriad anatomic constraints imposed by the proximity to the coronary ostia, aortic root/valve, and brachiocephalic trunk. Use of TEVAR in asymptomatic, uncomplicated, chronic Stanford

type B dissection is also controversial, with mixed survival benefit results when comparing TEVAR to optimized medical therapy. Relative contraindications to TEVAR include inadequate proximal or distal seal zones, aortic size discrepancies with respect to manufacturer guidelines, inadequate access, and extensive circumferential thrombus or atheroma at the desired landing zones.

Imaging plays a vital role in the pre- and post-intervention assessment of TEVAR patients. Accurate characterization of pathology and evaluation for high-risk anatomic features are necessary in the planning phase, whereas careful assessment for graft stability, aortic lumen diameter, and presence of endoleak are paramount in the follow-up period. As imaging studies carry inherent risk, careful attention must be paid to utilize the most efficacious study that will limit morbidity to the patient while identifying important complications before they become problematic. One finding that has become increasingly clear is that the thoracic aorta demonstrates dynamic changes following TEVAR. As the natural history of post-TEVAR patients evolves, the importance of these gradual changes will become clearer. For example, up to 73% of patients undergoing repair of acute type B aortic dissection will show aortic growth or new aneurysm at 5 years following TEVAR. Although reintervention is not necessary in all cases, close follow-up is mandatory given the propensity for dynamic vascular changes over time. Therefore, TEVAR should be thought of more as a chronic management tool than as definitive intervention.

Overview of Imaging Modalities

A variety of imaging modalities are available for the evaluation and follow-up of thoracic aortic pathology. Advances in imaging technology over the past 2 decades have greatly expanded the role of noninvasive cross-sectional imaging in the pre- and post-intervention periods. Computed tomography angiography (CTA) and, to a slightly lesser extent, magnetic resonance angiography (MRA) are now the preferred modalities in the assessment of the thoracic aorta given superior anatomic accuracy, capacity to discern relevant complications, and ability to infer dynamic vascular information. Catheter angiography has largely been replaced by CTA and MRA for diagnostic evaluation but remains a useful tool in cases where acute intervention is required. Ultrasound (US), echocardiography, radiography, and select nuclear medicine studies currently play an adjunctive role in the evaluation and follow-up of thoracic aortic disease and are principally utilized to answer specific anatomic and prognostic questions. A variety of factors contribute to the appropriateness of each imaging study, including acuity of the pathologic process, planned intervention, patient age, medical comorbidities, and endograft composition.

For the purposes of distinguishing between computed tomography (CT) and CTA, American College of Radiology (ACR) Appropriateness Criteria topics use the definition in the [Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography \(CTA\)](#)

:

"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3D renderings."

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and reconstructions/reformats. Only in CTA, however, is 3-D rendering a required element. This corresponds to the definitions that the Centers for Medicare & Medicaid Services has applied to the Current Procedural Terminology codes.

Discussion of Procedures by Variant

Variant 1: Planning for Pre-thoracic Endovascular Repair (TEVAR) of Thoracic Aorta Disease

Computed Tomography Angiography

Multidetector CT is the imaging modality of choice for preoperative assessment prior to TEVAR because of short scan times and superior spatial and temporal resolution. CTA is unmatched in its ability to provide isotropic data as well as robust and homogeneous intraluminal contrast enhancement. In cases of proximal thoracic aorta pathology, electrocardiography (ECG) gating can help achieve motion-free images along with ideal contrast enhancement. Acquisition of thin-section (0.5- to 2.0-mm) axial images with

subsequent reconstruction of multiplanar reformats, maximum-intensity projections (MIPs), curved planar reformats, and volume-rendered images allows for precise assessment of aortic anatomy. Centerline or double oblique measurements are critical to avoid errors based on aortic obliquity; such measurements are easily obtained with modern postprocessing software. More advanced postprocessing techniques such as 3-D virtual angioscopy, which affords a virtual endoluminal view, have shown utility in the surgical planning period. Because thoracic aorta pathology often extends to involve the abdominal aorta, imaging of the chest, abdomen, and pelvis is standard in evaluation of vascular pathology.

CTA can also identify higher-risk features and findings that may predict higher rates of postintervention complications. For example, it has been shown that increasing aortic tortuosity, which can be expressed as index values based on CTA measurements, is associated with increased risk of endoleak, stroke, and reduced survival following TEVAR for thoracic aortic aneurysm. In patients with acute aortic dissection, the presence of a single entry, as opposed to multiple sites, is associated with higher aortic growth rates, possibly because of deranged inflow/outflow dynamics; CTA has been shown to reliably detect entry tears with 82% sensitivity and 100% specificity. When abdominal visceral branches are involved and there is potential for celiac trunk or superior mesenteric artery coverage by the stent graft, CTA can help determine the presence of collateral vessels. In the absence of collaterals, an open surgical or hybrid approach may be necessary to avoid visceral ischemia.

CTA may also be able to guide device selection. One complication following TEVAR is the development of a bird-beak endograft configuration in the proximal landing zone, which portends a higher risk of endoleak. This configuration results most commonly when the proximal landing zone sits within a highly curved or angulated aortic arch. Specially designed endografts that are less susceptible to these morphologic changes can therefore be selected when preoperative imaging identifies problematic anatomy.

An important subset of TEVAR is its use in repair of pathologies involving the aortic arch. A detailed understanding of the spatial relationship of the arch vessels and the luminal changes throughout the diseased arch is required for proper patient and device selection. Minimum proximal and distal landing-zone intervals are necessary, with reported values in the literature ranging from 20 to >50 mm. When the proximal landing zone approaches or overlaps the origin of the left subclavian artery, there is an increased possibility of endoleak; in such cases, embolization of the artery and/or vascular bypass may be considered. Several commercially available devices require a normal-caliber proximal aorta with narrow acceptable landing-zone diameter ranges; for example, a recently approved multibranch endograft system requires a proximal aortic landing-zone diameter between 24 and 30 mm, thereby severely limiting the potential patient population. Endograft sizing is of critical importance because an undersized graft may lead to fixation and sealing compromise, with resultant type I endoleaks and graft migration. It must be anticipated that most aortas increase in diameter over time as a result of age-related change and progression of aneurysmal disease in affected patients.

Although open repair is traditionally pursued for proximal aorta pathology, endovascular stent grafting is possible in certain cases of type A dissection and proximal thoracic aortic aneurysm. A 2011 study demonstrated a 98% technical success rate for TEVAR in the treatment of 45 patients with type A dissection in which the entry tear was at least 2.5 cm from the coronary ostia. Notably, transposition of the supra-aortic vessels was necessary in nearly half of the patients in this study in order to ensure an adequate landing zone. Other authors recommend a minimum distance of 1 cm from the intimal tear entry site to the sinotubular junction and brachiocephalic trunk. CTA is essential in planning for these cases to avert compromise of coronary and brachiocephalic circulation as well as aortic valve dysfunction.

An essential aspect of pre-TEVAR planning is evaluation of the iliofemoral vasculature. Thoracic aorta endografts tend to be larger than their abdominal counterparts, requiring insertion sheaths with outer diameters up to 27 French. For this reason, a minimum vessel diameter of at least 8 to 9 mm is preferred. Additionally, increased vessel depth, degree of femoral artery calcification, and iliofemoral tortuosity have been shown to be negative predictors of percutaneous TEVAR success. All of these variables are readily evaluable with CTA and, in conjunction with sound clinical judgment, can be used to avoid the dreaded complication of iliac disruption necessitating open surgical repair. In cases of unfavorable anatomy,

surgical or endovascular conduits have been shown to reliably facilitate endovascular repair.

The radiation dose associated with properly performed CT examinations in the evaluation of thoracic aortic disease is not of significant concern. Potential nephrotoxicity from iodinated contrast in patients with impaired renal function is the primary concern in this patient population, although the benefits of obtaining key diagnostic information typically outweigh the low risk of developing contrast-induced nephropathy. Utilization of modern CT optimization techniques, such as high-pitch spiral CT imaging, low kilovolt (peak) (kV[p]) imaging, wide-area detectors, and iterative reconstruction techniques, allows for lower volumes of contrast and lower radiation dose with adequate diagnostic image quality.

Computed Tomography

Unenhanced CT is useful for identification of aortic size, acute IMH, and aortic calcification. In conjunction with CTA, sensitivity for detection of IMH is as high as 96%, and sensitivity and specificity for detection of the intimal flap in aortic dissection approach 100%. Moreover, unenhanced CT can delineate complications related to acute aortic syndromes such as mediastinal/pericardial hemorrhage and rupture. The addition of CTA allows for comprehensive assessment of other sequelae, including end-organ ischemia, acute aortic valvular insufficiency, intravascular thrombus, and supra-aortic, coronary, and mesenteric vascular involvement.

The use of contrast-enhanced CT and multiphase CT (without and with contrast) can provide similar information to CTA with regard to the anatomic extent of vascular pathology. Often, such studies are pursued to investigate other clinical questions or vague presentations and incidentally reveal significant vascular findings in the thoracic aorta. The lack of standard thin-section image acquisition, arterial-phase bolus timing, and 3-D renderings with these techniques is the principal limitation, and therefore CTA is the preferred imaging modality for the dedicated workup of thoracic aorta diseases.

Magnetic Resonance Angiography

Similar to CT, magnetic resonance imaging (MRI) of the thoracic aorta can be performed with and without intravenous contrast. The principle advantage of MRI over CT is the lack of ionizing radiation, making it a particularly attractive imaging option in young patients. MRI is a more time-consuming study than CT, necessitating a stable patient. Importantly, MRI confers similar sensitivity and specificity as CTA and transesophageal echocardiography (TEE) for detection of dissection flaps, although like TEE it is less accurate for detection of branch vessel involvement.

There are a variety of unenhanced MRA techniques, including time of flight, phase-contrast imaging, ECG-gated fast spin-echo, and steady-state free precession (SSFP). SSFP, for example, has been shown to have equal accuracy for the assessment of aortic diameter compared to contrast-enhanced MRA (CE-MRA). The SSFP technique is also useful for visualization of dissection flaps. General limitations with unenhanced MRA include loss of signal due to turbulent flow, long acquisition times, susceptibility to field inhomogeneity and motion, and the need for considerable patient cooperation for sequences requiring breath holding.

CE-MRA using 3-D spoiled gradient-echo sequences is the preferred MRI technique for thoracic aortic imaging, providing superior arterial signal, high spatial and contrast resolution, and rapid data acquisition during a single breath hold. ECG gating may be added for motion-free evaluation of the ascending aorta and aortic root. Similar to the typical multiphasic CTA protocol, CE-MRA studies generally consist of unenhanced, arterial, and delayed-phase images. Various triggering methods can be used to ensure adequate gadolinium contrast opacification. Because the images are acquired in a near-isotropic fashion, similar multiplanar reformats to those used in CTA can be produced. In addition to characterizing the extent of aortic pathology and providing precise, highly reproducible aortic measurements, CE-MRA has particular efficacy in delineation of mural thrombus versus intramural blood when CT results are equivocal. It is also useful in the differentiation of aortic wall inflammation from intramural hemorrhage and atheroma. A point of caution in the interpretation of MRA is to use source images for measurements, as MIP images may obscure the vessel wall and lead to underestimation of lumen size.

More advanced magnetic resonance (MR) applications allow flow mapping via time-resolved imaging

techniques. Such techniques allow for the evaluation of abnormal vascular anatomy, atherosclerotic plaque burden, collateral blood flow, and hemodynamic parameters in the involved segment of aorta.

Although CE-MRA is preferred for the aforementioned reasons, certain situations exist in which unenhanced MRA is desirable. These include patients with poor intravenous access; advanced, dialysis-dependent renal failure with glomerular filtration rate $<30 \text{ mL/min/1.73 m}^2$ (because of the risk of nephrogenic systemic fibrosis); and pregnancy (because of the possible teratogenic effects of gadolinium-based contrast agents).

Aortography

Catheter angiography has largely been replaced by cross-sectional imaging in the evaluation of patients with suspected aortic pathology. An exception is in cases of coexisting malperfusion involving the coronary, visceral, or cerebral circulations. In such cases, angiography allows for evaluation and possible revascularization of the affected vascular bed along with further characterization of aortic pathology. Angiography has gained traction in the hybrid operating-room approach to acute type A aortic dissection, in which diagnostic and interventional angiography techniques are combined with open surgical repair. Catheter angiography allows for assessment of luminal size of the iliofemoral system but is limited in its ability to assess for atherosclerotic plaque burden. Additionally, digital subtraction angiography remains the gold standard for preintervention visualization of the artery of Adamkiewicz, an important consideration when there is high concern for spinal cord ischemia.

Echocardiography

In hemodynamically unstable patients, transthoracic echocardiography (TTE) is a useful imaging study for rapid evaluation of valvular function, aortic root dilation, and thoracic aortic dissection. This can be further supplemented with TEE, which allows for comparatively superior anatomic evaluation and can be left in place for intraoperative monitoring. Although offering comparable sensitivities to CT and MRI for detection of thoracic aortic dissection, TEE is limited in its sensitivity for detection of branch vessel involvement and delineation of pathology below the gastroesophageal junction. Echocardiography can also evaluate for concomitant cardiovascular disease and identify patients in whom coronary revascularization or valvular repair may be indicated.

Ultrasound Intravascular

Similar to intraprocedural TEE, intravascular US (IVUS) is an additional adjunctive imaging tool that can aid in optimal visualization of intimal tears, ideal endograft positioning, assessment of branch vessel patency, and detection of abnormal flow within the false lumen and excluded aneurysm sac following endograft placement.

Ultrasound Iliofemoral Arteries

In cases where thoracic aortic disease does not extend into the abdomen and no cross-sectional imaging of the iliofemoral system is available, US duplex Doppler of the iliofemoral arteries is useful for assessing adequate access. US duplex Doppler allows for assessment of vessel diameter and plaque burden along the anterior aspect of the vessel. In one recent series examining the use of US-guided femoral access in abdominal aortic endovascular aneurysm repair patients, intraoperative US guidance was shown to significantly reduce operative time and access wound complications. Although similar dedicated studies are not available for TEVAR, the underlying principle is directly transferrable. Similarly, IVUS at the time of intervention has been shown to provide reliable information regarding iliofemoral morphology and atherosclerotic disease burden.

Chest Radiography

Chest radiographs will demonstrate abnormalities in a large percentage of patients with acute thoracic aorta pathology. For example, in patients presenting with acute aortic dissection, $>80\%$ demonstrated chest radiograph abnormalities, with mediastinal widening seen in just over 50% of cases. However, radiography can only alert to an underlying abnormality and provides no specific information regarding

type of pathology or detailed anatomic information necessary for interventional planning.

FDG-PET/CT

Nuclear medicine studies play a limited role in the workup of acute aortic pathology. In patients presenting with acute type B aortic dissection, greater uptake of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG) in the aortic wall as seen on positron emission tomography (PET)/CT has been shown to predict rupture and dissection propagation.

Variant 2: Follow-up for Post-thoracic Endovascular Repair (TEVAR) of Thoracic Aortic Disease

Computed Tomography Angiography

CTA is the optimal modality for post-TEVAR imaging given its sensitivity for the detection of endoleaks, changes in aortic/aneurysm diameter, evaluation of false lumen thrombosis, and assessment for device migration and integrity. As discussed previously, one of the limitations of TEVAR is the high rate of reintervention. Although reintervention rates are lower for aneurysmal disease, trauma, and IMH, routine surveillance imaging is requisite regardless of aortic pathology. Although there are no universally accepted guidelines, lifelong follow-up is recommended following TEVAR because endoleaks can develop at any time following intervention. Routine postprocedure imaging protocols typically entail follow-up within 30 days of the procedure, at 3 to 12 months, and regular surveillance imaging at 6- to 12-month intervals thereafter depending on stability. These intervals may gradually be lengthened if stability or improvement is documented over several examinations. Future directions for surveillance will almost certainly be individualized based on personal risk factors. In patients in whom no endoleak is observed, aneurysm sac size is shrinking, and proximal and distal seal zones are adequate, less frequent surveillance imaging can safely be pursued.

The optimal CTA protocol for TEVAR follow-up is not well defined. Most commonly a triphasic protocol is performed with acquisition of unenhanced, arterial, and delayed-phase (60–120 seconds following injection) imaging. The utility of the unenhanced phase is to differentiate extraluminal calcification or postendoleak intervention material from extraluminal contrast seen on contrast-enhanced images. Although comprehensive, such a protocol delivers a high radiation dose. Some institutions employ a late delayed phase of 300 seconds to better visualize low-flow endoleaks.

With regard to endoleak, type I endoleaks occurring at the proximal (Ia) or distal (Ib) landing zones are the most common cause for reintervention following TEVAR, occurring in up to 15% of cases. In contrast to abdominal aorta endovascular repair where type II endoleaks are most common, type II endoleaks occur in a small percentage of TEVAR patients, likely because of fewer patent collateral vessels in the thorax compared to the abdomen. Furthermore, type II endoleaks are not associated with increased risk of thoracic aorta rupture and are often managed conservatively. Types III, IV, and V endoleaks occur much less frequently, with type III being the only subtype other than type I to require immediate therapy.

It has been shown that luminal diameter as determined from 3-D measurements correlates well with aortic luminal area during the postoperative period and can be used as a proxy for luminal blood flow. This applies to both true and false lumens in cases of dissection, although the relationship becomes less clear with large false lumen diameters because of the propensity for complex luminal configuration. Serial evaluation of true and false lumen diameters via CTA in the postintervention period is a marker for vascular remodeling. Recent midterm results from the VIRTUE Registry demonstrate similar rates of vascular remodeling in patients with uncomplicated acute and subacute type B dissections. Along with other studies demonstrating a mortality benefit in the treatment of subacute to chronic uncomplicated type B dissections, these data suggest that TEVAR is a viable alternative treatment option in the management of these patients compared to optimized medical therapy.

Partial false lumen thrombosis is an important predictor of regional luminal growth and reintervention rate. Although incompletely understood, this is postulated to be due to a regional increase in luminal pressure owing to small diameter. Chronic dissections tend to show lesser degrees of remodeling, perhaps because of the frequent presence of multiple intimal tears and development of intercostal

collaterals in these patients. When there is a question of false lumen thrombosis status, the absence of contrast enhancement on arterial and early delayed-phase CTA does not necessarily indicate complete thrombosis given the possibility of a low-flow state. In such cases, more-delayed imaging demonstrates higher sensitivity for detection of partial thrombosis.

Similar to the findings seen in TEVAR for aortic dissection, there is significant vascular remodeling when TEVAR is used for IMH or PAU, with near-complete normalization of aortic diameter at 1 year as measured on CTA.

CTA is also the preferred imaging modality of choice for evaluation of endograft infection, one of the most serious complications following TEVAR. A recent study demonstrated that in the small number of patients with an infected endograft, CTA suggested the diagnosis in 78% of cases, with the most common findings being periaortic inflammation and erosion into surrounding structures.

The principal disadvantages of CTA in the follow-up period are potential nephrotoxicity and cumulative radiation dose, particularly in younger patients. A study evaluating radiation exposure during TEVAR and subsequent follow-up found that cumulative lifetime radiation exposure in these patients is likely to exceed 350 mSv, conferring an increased lifetime risk of at least 2.7% for developing solid-organ malignancy or leukemia. The development of ever-advanced iterative reconstruction algorithms permits the use of lower tube energies, thereby allowing for reduced patient radiation exposure. A recent study highlighted radiation dose reductions ranging from 63% to 69% at standard kV(p) using a fully iterative reconstruction algorithm as compared to standard filtered back-projection without appreciable changes in conspicuity of endoleaks or in-stent thrombosis. Dual-energy acquisition offers the possibility of eliminating the unenhanced phase via the creation of a virtual noncontrast image set. Another recent study demonstrated near-perfect correlation between single- and dual-phase dual-energy scans in comparison to a traditional 3-phase protocol, with 19.5% and 64.1% less radiation exposure, respectively.

Computed Tomography

Although not ideal given the inability to directly detect endoleaks, unenhanced CT can still offer valuable follow-up information in TEVAR patients with chronic renal insufficiency and stent grafts not amenable to MRA. Unenhanced CT is useful in the assessment of graft migration, aortic rupture, and delineation of vascular calcifications, hematoma, and surgical material that could otherwise be confused for endoleak on CTA examinations. Additionally, by using aneurysm sac diameter as a proxy for graft and anastomotic integrity, unenhanced CT can indirectly suggest endoleak if sac volume increases over time by more than 2%. In patients with stable findings on early postintervention imaging and a low risk of graft complications, follow-up with unenhanced CT complemented by CTA when questions arise may be a viable strategy.

Similar to the preprocedure discussion, non-vascular-dedicated contrast-enhanced CT and multiphase CT (without and with contrast) examinations may provide useful post-TEVAR information and alert the radiologist to complications but are suboptimal compared to CTA, given the lack of standard thin-section image acquisition, specific bolus timing, and 3-D renderings.

Magnetic Resonance Angiography

MRI following TEVAR suffers from severe susceptibility to artifacts relating to the stainless steel used in many stent graft types, obscuring surrounding relevant anatomy and limiting evaluation for endoleak. One particular group in which MRI is a preferred imaging modality is patients in whom nitinol stents are placed. This is because these endografts do not produce susceptibility artifacts, thereby allowing adequate visualization of the underlying vasculature. Various studies have demonstrated comparable to superior sensitivities in detection of endoleak with MRA compared to CTA when such stents are used. Additional research has shown that in patients with MR-compatible endografts, unenhanced MRA can reliably assess stent position and geometry, whereas CE-MRA can sufficiently evaluate endograft hemodynamics and aortic diameter.

A principal advantage of MRI in the follow-up period is its lack of ionizing radiation. In younger patients

in whom cumulative radiation dose from repeat CT examinations is of particular concern, placement of an MR-compatible endograft should strongly be considered so that routine MRI surveillance can be obtained. As noted previously, the use of CE-MRA is limited in cases of severe renal dysfunction and pregnancy.

Aortography

Given its invasiveness, catheter angiography is not a routine surveillance tool following TEVAR. However, in cases where significant endoleaks are identified on cross-sectional imaging or where the origin of endoleak is unclear, catheter angiography is indispensable for further anatomic characterization as well as definitive treatment.

Echocardiography

In cases where the extent of residual aortopathy is confined to the aortic root or proximal aorta dilation, TTE may play an adjunctive surveillance role, reducing the frequency of CT or MR surveillance. TEE provides suboptimal evaluation of suspected endoleak and should be considered only in patients in whom CTA is precluded because of severe renal dysfunction or contrast allergy.

Ultrasound

US duplex Doppler is an alternative modality for follow-up of abdominal aortic endovascular aneurysm repair with high specificity for detection of endoleaks and high accuracy for evaluation of aneurysm sac size. The addition of contrast material makes US an even more sensitive and specific test than CTA for characterization of endoleaks. Its use in TEVAR is impractical in the chest given poor acoustic windows but may provide diagnostic information for the abdominal aspect of the stent graft.

Chest Radiography

Radiography in the postintervention period has traditionally been used to evaluate for stent migration and integrity. However, given ever-increasing improvements in CT imaging quality as well as the low incidence of stent graft fractures with currently available endograft devices, the utility of radiographic follow-up is increasingly limited.

Nuclear Medicine

Recent research using the experimental radiotracer technetium Tc-99m–human serum albumin diethylenetriamine pentaacetic acid has shown similar sensitivity to CTA for the detection of endoleaks following endovascular repair. Image quality is unaffected by the presence of streak and susceptibility artifacts related to the stent, endovascular coils, or embolization material. Furthermore, given the high labeling yield and prolonged retention in the blood pool, extraluminal accumulation of radiotracer is highly specific for endoleak. Although not likely to be a widely implemented technique, this imaging modality may be of use in patients with chronic renal insufficiency or suspected slow-filling endoleaks or in cases where prior endoleak embolization material causes prohibitive artifact on CTA.

Summary of Recommendations

TEVAR can be successfully used to treat a wide variety of acute and chronic thoracic aorta pathologies. Imaging in the preintervention and postintervention period is critical for surgical planning and evaluation of complications.

In the planning stage of TEVAR, CTA is the imaging modality of choice for assessment of thoracic aortic pathology and complications, given its superior accuracy. CE-MRA is an acceptable alternative in stable patients.

Lifelong imaging follow-up is necessary in TEVAR patients as endoleaks may develop at any time. The exact surveillance interval is unclear and may be procedure and patient specific.

In the postintervention follow-up evaluation, CTA is the imaging modality of choice, given its sensitivity for the detection of endoleaks, changes in aortic/aneurysm diameter, evaluation of false lumen thrombosis, and assessment for device migration and integrity. MRA can provide equivalent information and is preferred for long-term follow-up of younger patients given the lack of ionizing

radiation, but it can be used only with MR-compatible stent grafts.

Abbreviations

ACR, American College of Radiology
CT, computed tomography
CTA, computed tomographic angiography
FDG-PET, fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography
IV, intravenous
MRA, magnetic resonance angiography
MRI, magnetic resonance imaging
US, ultrasound

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
0	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢ ☢	0.1-1 mSv	0.03-0.3 mSv
☢ ☢ ☢	1-10 mSv	0.3-3 mSv
☢ ☢ ☢ ☢	10-30 mSv	3-10 mSv
☢ ☢ ☢ ☢ ☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

Clinical Algorithm(s)

Algorithms were not developed from criteria guidelines.

Scope

Disease/Condition(s)

Aortic pathologies, including trauma, aneurysm, dissections, intramural hematoma (IMH), penetrating atherosclerotic ulcer (PAU), and persistent congenital malformations such as aortic coarctation, for which thoracic endovascular aortic repair (TEVAR) may be used

Guideline Category

Evaluation

Management

Treatment

Clinical Specialty

Cardiology

Geriatrics

Internal Medicine

Nuclear Medicine

Radiology

Thoracic Surgery

Intended Users

Advanced Practice Nurses

Health Care Providers

Health Plans

Hospitals

Managed Care Organizations

Physician Assistants

Physicians

Students

Utilization Management

Guideline Objective(s)

To evaluate the appropriateness of imaging procedures for thoracic aorta interventional planning and follow-up

Target Population

Patients undergoing treatment for a wide range of aortic pathologies, including trauma, aneurysm, dissections, intramural hematoma (IMH), penetrating atherosclerotic ulcer (PAU), and persistent congenital malformations such as aortic coarctation, for which thoracic endovascular aortic repair (TEVAR) may be used

Interventions and Practices Considered

1. Computed tomography angiography (CTA)
 - Chest abdomen pelvis with intravenous (IV) contrast
 - Chest with IV contrast
2. Magnetic resonance angiography (MRA)
 - Chest abdomen pelvis with IV contrast
 - Chest abdomen pelvis without IV contrast
 - Chest with IV contrast
 - Chest without IV contrast
3. Ultrasound (US)
 - Duplex Doppler, iliofemoral arteries
 - Duplex Doppler, aorta abdomen
 - Echocardiography transesophageal

- Echocardiography transthoracic resting
- Intravascular aorta
- 4. Aortography, chest abdomen pelvis
- 5. Computed tomography (CT)
 - Chest abdomen pelvis without IV contrast
 - Chest abdomen pelvis without and with IV contrast
 - Chest abdomen pelvis with IV contrast
 - Chest without IV contrast
 - Chest without and with IV contrast
 - Chest with IV contrast
- 6. Fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET), chest abdomen pelvis
- 7. X-ray, chest

Major Outcomes Considered

- Utility of imaging procedures in thoracic aorta interventional planning and follow-up
- Sensitivity, specificity, and accuracy of imaging procedures in thoracic aorta interventional planning and follow-up

Methodology

Methods Used to Collect/Select the Evidence

Hand-searches of Published Literature (Primary Sources)

Hand-searches of Published Literature (Secondary Sources)

Searches of Electronic Databases

Description of Methods Used to Collect/Select the Evidence

Literature Search Summary

A literature search was conducted in May 2015 to identify evidence for the *ACR Appropriateness Criteria® Thoracic Aorta Interventional Planning and Follow-up* topic. Using the search strategy described in the literature search companion (see the "Availability of Companion Documents" field), 364 articles were found. Eighty-three articles were used in the topic. Two hundred and eighty-one articles were not used due to either poor study design, the articles were not relevant or generalizable to the topic, or the results were unclear, misinterpreted, or biased.

The author added 8 citations from bibliographies, Web sites, or books that were not found in the literature search.

One citation is a supporting document that was added by staff.

See also the American College of Radiology (ACR) Appropriateness Criteria® literature search process document (see the "Availability of Companion Documents" field) for further information.

Number of Source Documents

The literature search conducted in May 2015 identified 83 articles that were used in the topic. The author added 8 citations from bibliographies, Web sites, or books that were not found in the literature search.

One citation is a supporting document that was added by staff.

Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

Rating Scheme for the Strength of the Evidence

Definitions of Study Quality Categories

Category 1 - The study is well-designed and accounts for common biases.

Category 2 - The study is moderately well-designed and accounts for most common biases.

Category 3 - The study has important study design limitations.

Category 4 - The study or source is not useful as primary evidence. The article may not be a clinical study, the study design is invalid, or conclusions are based on expert consensus.

The study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);

Or

The study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;

Or

The study is an expert opinion or consensus document.

Category M - Meta-analysis studies are not rated for study quality using the study element method because the method is designed to evaluate individual studies only. An "M" for the study quality will indicate that the study quality has not been evaluated for the meta-analysis study.

Methods Used to Analyze the Evidence

Systematic Review with Evidence Tables

Description of the Methods Used to Analyze the Evidence

The topic author assesses the literature then drafts or revises the narrative summarizing the evidence found in the literature. American College of Radiology (ACR) staff drafts an evidence table based on the analysis of the selected literature. These tables rate the study quality for each article included in the narrative.

The expert panel reviews the narrative, evidence table and the supporting literature for each of the topic-variant combinations and assigns an appropriateness rating for each procedure listed in the variant table(s). Each individual panel member assigns a rating based on his/her interpretation of the available evidence.

More information about the evidence table development process can be found in the ACR Appropriateness Criteria® Evidence Table Development document (see the "Availability of Companion Documents" field).

Methods Used to Formulate the Recommendations

Description of Methods Used to Formulate the Recommendations

Rating Appropriateness

The American College of Radiology (ACR) Appropriateness Criteria (AC) methodology is based on the RAND Appropriateness Method. The appropriateness ratings for each of the procedures or treatments included in the AC topics are determined using a modified Delphi method. A series of surveys are conducted to elicit each panelist's expert interpretation of the evidence, based on the available data, regarding the appropriateness of an imaging or therapeutic procedure for a specific clinical scenario. The expert panel members review the evidence presented and assess the risks or harms of doing the procedure balanced with the benefits of performing the procedure. The direct or indirect costs of a procedure are not considered as a risk or harm when determining appropriateness. When the evidence for a specific topic and variant is uncertain or incomplete, expert opinion may supplement the available evidence or may be the sole source for assessing the appropriateness.

The appropriateness is represented on an ordinal scale that uses integers from 1 to 9 grouped into three categories: 1, 2, or 3 are in the category "usually not appropriate" where the harms of doing the procedure outweigh the benefits; and 7, 8, or 9 are in the category "usually appropriate" where the benefits of doing a procedure outweigh the harms or risks. The middle category, designated "may be appropriate," is represented by 4, 5, or 6 on the scale. The middle category is when the risks and benefits are equivocal or unclear, the dispersion of the individual ratings from the group median rating is too large (i.e., disagreement), the evidence is contradictory or unclear, or there are special circumstances or subpopulations which could influence the risks or benefits that are embedded in the variant.

The ratings assigned by each panel member are presented in a table displaying the frequency distribution of the ratings without identifying which members provided any particular rating. To determine the panel's recommendation, the rating category that contains the median group rating without disagreement is selected. This may be determined after either the first or second rating round. If there is disagreement after the first rating round, a conference call is scheduled to discuss the evidence and, if needed, clarify the variant or procedure description. If there is disagreement after the second rating round, the recommendation is "May be appropriate."

This modified Delphi method enables each panelist to articulate his or her individual interpretations of the evidence or expert opinion without excessive influence from fellow panelists in a simple, standardized, and economical process. For additional information on the ratings process see the [Rating Round Information](#) document.

Additional methodology documents, including a more detailed explanation of the complete topic development process and all ACR AC topics can be found on the [ACR Web site](#) (see also the "Availability of Companion Documents" field).

Rating Scheme for the Strength of the Recommendations

Not applicable

Cost Analysis

A formal cost analysis was not performed and published cost analyses were not reviewed.

Method of Guideline Validation

Internal Peer Review

Description of Method of Guideline Validation

Criteria developed by the Expert Panels are reviewed by the American College of Radiology (ACR) Committee on Appropriateness Criteria.

Evidence Supporting the Recommendations

Type of Evidence Supporting the Recommendations

The recommendations are based on analysis of the current medical evidence literature and the application of the RAND/UCLA appropriateness method and expert panel consensus.

Summary of Evidence

Of the 92 references cited in the *ACR Appropriateness Criteria® Thoracic Aorta Interventional Planning and Follow-up* document, 59 are categorized as therapeutic references including 3 well-designed studies, 30 good-quality studies, and 1 quality study that may have design limitations. Additionally, 33 references are categorized as diagnostic references including 1 well-designed study, 3 good-quality studies, and 8 quality studies that may have design limitations. There are 44 references (including 19 diagnostic references and 25 therapeutic references) that may not be useful as primary evidence.

Although there are references that report on studies with design limitations, 37 well-designed or good-quality studies provide good evidence.

Benefits/Harms of Implementing the Guideline Recommendations

Potential Benefits

Imaging plays a vital role in the pre- and postintervention assessment of thoracic endovascular aortic repair (TEVAR) patients. Accurate characterization of pathology and evaluation for high-risk anatomic features are necessary in the planning phase, whereas careful assessment for graft stability, aortic lumen diameter, and presence of endoleak are paramount in the follow-up period. In the planning stage of TEVAR, computed tomography angiography (CTA) is the imaging modality of choice for assessment of thoracic aortic pathology and complications, given its superior accuracy. In the postintervention follow-up evaluation, CTA is the imaging modality of choice, given its sensitivity for the detection of endoleaks, changes in aortic/aneurysm diameter, evaluation of false lumen thrombosis, and assessment for device migration and integrity.

Potential Harms

- A point of caution in the interpretation of magnetic resonance imaging (MRA) is to use source images for measurements, as maximum-intensity projections (MIP) images may obscure the vessel wall and lead to underestimation of lumen size.
- The radiation dose associated with properly performed computed tomography (CT) examinations in the evaluation of thoracic aortic disease is not of significant concern. Potential nephrotoxicity from iodinated contrast in patients with impaired renal function is the primary concern in this patient population, although the benefits of obtaining key diagnostic information typically outweigh the low risk of developing contrast-induced nephropathy.
- The principal disadvantages of computed tomography angiography (CTA) in the follow-up period are potential nephrotoxicity and cumulative radiation dose, particularly in younger patients. A study

evaluating radiation exposure during thoracic endovascular repair (TEVAR) and subsequent follow-up found that cumulative lifetime radiation exposure in these patients is likely to exceed 350 mSv, conferring an increased lifetime risk of at least 2.7% for developing solid-organ malignancy or leukemia.

- There are certain situations exist in which unenhanced MRA is desirable. These include patients with poor intravenous access; advanced, dialysis-dependent renal failure with glomerular filtration rate $<30 \text{ mL/min/1.73 m}^2$ (because of the risk of nephrogenic systemic fibrosis); and pregnancy (because of the possible teratogenic effects of gadolinium-based contrast agents).

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults. Additional information regarding radiation dose assessment for imaging examinations can be found in the American College of Radiology (ACR) Appropriateness Criteria® Radiation Dose Assessment Introduction document (see the "Availability of Companion Documents" field).

Contraindications

Contraindications

Relative contraindications to thoracic endovascular repair (TEVAR) include inadequate proximal or distal seal zones, aortic size discrepancies with respect to manufacturer guidelines, inadequate access, and extensive circumferential thrombus or atheroma at the desired landing zones.

Qualifying Statements

Qualifying Statements

- The American College of Radiology (ACR) Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the U.S. Food and Drug Administration (FDA) have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.
- ACR seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by

representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Implementation of the Guideline

Description of Implementation Strategy

An implementation strategy was not provided.

Institute of Medicine (IOM) National Healthcare Quality Report Categories

IOM Care Need

Getting Better

Living with Illness

IOM Domain

Effectiveness

Safety

Identifying Information and Availability

Bibliographic Source(s)

Bonci G, Steigner ML, Hanley M, Braun AR, Desjardins B, Gaba RC, Gage KL, Matsumura JS, Roselli EE, Sella DM, Strax R, Verma N, Weiss CR, Dill KE, Expert Panels on Vascular Imaging and Interventional Radiology. ACR Appropriateness Criteria® thoracic aorta interventional planning and follow-up. Reston (VA): American College of Radiology (ACR); 2017. 17 p. [92 references]

Adaptation

Not applicable: The guideline was not adapted from another source.

Date Released

2017

Guideline Developer(s)

American College of Radiology - Medical Specialty Society

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Guideline Committee

Committee on Appropriateness Criteria, Expert Panels on Vascular Imaging and Interventional Radiology

Composition of Group That Authored the Guideline

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Financial Disclosures/Conflicts of Interest

All panel members, authors, and chairs must complete a Conflict of Interest and Expertise Survey annually, disclosing any actual or potential conflicts related to duties and responsibilities on the panel.

Guideline Status

This is the current release of the guideline.

This guideline meets NGC's 2013 (revised) inclusion criteria.

Guideline Availability

Available from the [American College of Radiology \(ACR\) Web site](#) .

Availability of Companion Documents

The following are available:

ACR Appropriateness Criteria®. Overview. Reston (VA): American College of Radiology; 2015 Oct. 3 p. Available from the [American College of Radiology \(ACR\) Web site](#) .

ACR Appropriateness Criteria®. Literature search process. Reston (VA): American College of Radiology; 2015 Feb. 1 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Evidence table development. Reston (VA): American College of Radiology; 2015 Nov. 5 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Topic development process. Reston (VA): American College of Radiology; 2015 Nov. 2 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Rating round information. Reston (VA): American College of Radiology; 2015 Apr. 5 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Radiation dose assessment introduction. Reston (VA): American College of Radiology; 2017. 4 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Manual on contrast media. Reston (VA): American College of Radiology; 2017. 125 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria®. Procedure information. Reston (VA): American College of Radiology; 2017 Mar. 4 p. Available from the [ACR Web site](#) .

ACR Appropriateness Criteria® thoracic aorta interventional planning and follow-up. Evidence table. Reston (VA): American College of Radiology; 2017. 46 p. Available from the [ACR Web site](#)

ACR Appropriateness Criteria® thoracic aorta interventional planning and follow-up. Literature search. Reston (VA): American College of Radiology; 2017. 1 p. Available from the [ACR Web site](#)

Patient Resources

None available

NGC Status

This NGC summary was completed by ECRI Institute on June 23, 2017.

This NEATS assessment was completed by ECRI Institute on June 28, 2017. The information was verified by the guideline developer on July 25, 2017.

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